SYNOPSIS OF RESEARCH PROJECT

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9. Introduction

Agriculture is one such field where the abundance of information paradoxically constrains its effective utilization. Cost of cultivation is one fine example of such a database, where its technical and policy analysis is continuously found wanting (Raghavan, 2008; Verma, 2023). Nevertheless, everything in agriculture revolves around cost of cultivation. Right from the adoption of technology to the metrics involving productivity and efficiency of inputs, cost and returns take the centre stage. Only favourable cost and returns can influence farmers to bring about desirable changes in cropping pattern, adopt a newly released variety, adapt the recommendation of a university, or carry out profitable adjustments in the supply of crop produce. Studies capturing the structural changes in input costs and returns over time effectively bring out the changing status of farmers and changes in the viability of their profession over time (Sen and Bhatia, 2004). Microanalysis comprising costs and returns alone can answer why some crops/some regions fare well in terms of total factor productivity, or compare resource utilization and efficiency estimates across regions or crops.

Cost of cultivation dataset is one of the most unique kinds of dataset available in public domain, which is being rigorously collected since the early 1970-71 under the scheme entitled 'Comprehensive scheme for studying the cost of cultivation of principal crops in India' (DES, 2026) across the county, that too, covering the plot-wise data of the farmers identified by district-wise talukas of the major producing states under the selected crops. The availability of panel data on crop-wise input quantities, along with their associated costs and returns for thousands of farmers every single year from 1970-71, is sufficient enough for its tremendous exploitation in academics and research. Besides understanding the composition and trends of input costs and returns, the database can be effectively utilized to analyse the crop-wise feasibility at spatio-temporal disaggregated level, provided appropriate tools are used. On the contrary, despite the immense utility and rich availability of the data on cost and returns of the farmers, there are only a few serious works are available that capture the essence of panel data.

One such seminar work is of Sen and Bhatia (2004) who in their millennium study on the state of Indian farmers singularly utilized the cost of cultivation panel data to analyse the structure and composition of cost of returns of 20 major crops across 14 major states for the study period between 1970-71 to 1998-99. Apart from this voluminous work, running hundreds of pages, the studies using the panel data on cost and returns of crops either focus on individual crops across the states or individual states across the crops (Srivastava *et al*., 2017; Adak and Pramanik, 2024; and Mandal, 2024).

Taking a leaf out of the earlier studies, the present study attempts to utilize the available cost of cultivation data to discern state-wise insights for the country as a whole and district-wise insights for Gujarat in particular. Agriculture continues to be the backbone of the Indian economy, supporting the livelihoods of nearly half of the country's population and playing a critical role in ensuring food and nutritional security. It contributes significantly to national income, rural employment, and poverty alleviation, particularly in rain-fed and semi-arid regions where alternative sources of livelihood are limited. Within the agricultural sector, oilseed crops hold a special place due to their contribution to farm income, edible oil production, and employment generation. In recent years, oilseed production in India has shown a steady increase, reaching 42.609 million tonnes in 2024–25 (IBEF, 2025), reflecting the sector's growing importance in meeting domestic edible oil demand and supporting agro-industries.

Among oilseeds, groundnut (*Arachis hypogaea* L.), commonly known as peanut, is a multi-purpose crop of considerable economic and nutritional significance. Belonging to the

Fabaceae family, it is unique for its geocarpic nature, where flowers appear above ground but pods develop underground. Groundnut is cultivated primarily for its oil-rich seeds, which serve as a major source of edible oil and protein, and its haulms provide valuable fodder for livestock. Globally, India is among the leading producers of groundnut, with Gujarat, Andhra Pradesh, and Rajasthan being the top contributing states. In addition to its economic importance, groundnut enhances soil fertility through biological nitrogen fixation, making it a key component of sustainable crop rotations. Its adaptability to diverse agro-climatic conditions and multiple uses—ranging from oil extraction and food products to animal feed—underscore its significance in both subsistence and commercial agriculture.

Gujarat is the leading producer of groundnut in India, contributing 5.22 million tonnes out of the national total of 11.942 million tonnes in 2024–25, accounting for more than 40 per cent of total production (UPAG, GOI, 2025). However, groundnut cultivation in the state is largely rain-fed and therefore highly dependent on climatic conditions, input use, and the level of technology adoption. Under such conditions, improving productivity along with efficient use of available resources becomes essential for sustaining farm income. In this context, it becomes important to understand the sources of productivity growth. Total Factor Productivity (TFP) is commonly used to measure the portion of output growth that cannot be explained by changes in conventional inputs such as land, labour, and capital, and is generally associated with technological progress and efficiency improvements (Solow, 1957). However, as TFP is an aggregate measure, it does not clearly indicate how efficiently resources are being utilized at the farm level.

Technical efficiency (TE), therefore, assumes importance as it focuses on the ability of farmers to obtain maximum output from a given set of inputs or to minimize input use for a given level of output. It is measured as the ratio of actual output to the potential (frontier) output and reflects the extent of resource-use efficiency at the farm level. With rising input costs and limited scope for further input expansion, improving efficiency offers a practical approach to enhancing productivity.

Despite Gujarat's leading position in groundnut production, most existing studies are confined to state-level aggregate analysis, often overlooking district-level differences arising from socio-economic and agro-climatic factors. In particular, limited attention has been given to district-wise break-even dynamics and growth–instability trade-offs in input costs. Further, although total factor productivity has been examined in a broader context, its assessment at a

disaggregated level, along with technical efficiency, remains limited. As a result, a comprehensive understanding of regional variations in performance is still lacking.

Against this background, the present study attempts to examine groundnut cultivation in Gujarat from a district-wise perspective. By focusing on variations in efficiency, cost structures, and supply response, the study aims to identify key factors affecting farm performance across regions. The findings are expected to provide useful insights for improving resource allocation and enhancing productivity without increasing the financial burden on farmers. Strengthening technical efficiency can thus contribute to more sustainable agricultural growth and improved resilience of farming systems under changing economic conditions.

10. Practical Utility of the Research Project

While, on average, the gross cropped area (GCA) under groundnut cultivation hardly contributes to only 2.5 to 3.0 per cent to the total GCA in India in any given year, the crop is heavily concentrated in Gujarat to such an extent that not less than 13-14 per cent, on average, of the GCA of the state comes under its cultivation every other year. The crop performs also so well in the state that Gujarat tops in all three growth parameters of area, production, and productivity. Thereby, a systematic analysis of costs and returns of groundnut cultivation over time might throw more light on the structural changes in input-output ratios, which shall go a long way to bring about suitable policy prescriptions for Gujarat to maintain its comparative advantage. A comparative assessment of major groundnut producing states in the country will also be of help in exploring the areas in which the performance of the state can be sustained. Previous works also indicate that the highest levels of productivity does not necessarily translate into the highest levels of efficiency. If such is the case, the district-wise analysis of technical efficiency of farmers in Gujarat will be of help in understanding the status and contribution of technology in groundnut production and the scope of attaining optimal yield levels with less input usage, thereby, to maintain both productivity and efficiency in groundnut cultivation.

Therefore, the present study, entitled **"Total Factor Productivity and Efficiency Decomposition of Groundnut Cultivation in Gujarat and Major Producing States"** is being proposed with the overarching objective of assessing and comparing the total factor productivity and efficiency of groundnut cultivation in Gujarat and other major producing states in India. In addition, the district-wise comparison of total factor productivity and efficiency within Gujarat will also be taken up for micro-level insights on groundnut

cultivation in Gujarat. Going further, plot-wise analysis of break-even dynamics among farmers will also be taken up to understand the changes in the percentage of farmers breaking even and not even breaking even over time. The specific objectives to be taken up in the proposed study, and their associated hypotheses, are given hereunder.

11. Objectives

1. To compute and compare the state-wise structural changes and growth-instability trade-offs in cost and return indicators of groundnut cultivation;
2. To examine the changes in the spatio-temporal estimations of break-even output, acreage, and yield and determine the number of farmers not breaking even over time;
3. To comprehend the elasticities and sources of break-even output with respect to cost and price factors therein;
4. To analyse the role of input costs in determining acreage allocation of farmers and to estimate the associated short-run and long-run elasticities;
5. To study trends in total factor productivity (TFP), estimate the real cost of production, and assess the contribution of TFP to output growth; and
6. To determine the resource use efficiency and technical efficiency decomposition of groundnut cultivation at state and district levels for India and Gujarat, respectively.

11.1 Hypotheses

In tune with the objectives mentioned above, the proposed study will test the following working hypotheses:

1. There is no significant difference in the utilization pattern of input costs across spatio-temporal levels, and no significant trade-offs exist between growth and instability in input costs;
2. There is no significant change in the break-even dynamics of groundnut cultivation over time in Gujarat state and major producing states in India;
3. The elasticity of groundnut cultivation and its break-even components do not significantly differ from expected levels and show no significant variation;
4. Groundnut cultivation does not exhibit any significant supply response to changes in influencing factors over time; and
5. There is no significant trend in total factor productivity over time; and
6. Resource use and technical efficiency in groundnut cultivation do not significantly differ from optimal levels.

11.2 Limitations of the Study

The study period covers the plot-wise cost of cultivation data only from 2000-01 to 2021-22 in tune with its availability in public domain. Though the data being comprehensive and rigorous, covering plot-level information of thousands of farmers every single year, the socio-economic characteristics of the farmers go uncovered, which often influence the utilization, productivity, and efficiency of inputs. As the data are collected over block periods of three years each, the farmers remain unchanged and the study area (districts, talukas and villages) remain common only for the concerned block period, making it glaringly difficult for comparisons even at district-levels across block periods. Any further micro-level insights are possible only for one block period at a time. The findings of the study will be applicable only for the selected states and not for the country as a whole.

12. Review of Literature

The review of literature is one such exercise that gives direction to the research itself. As research begins to the probing questions about a problem statement at hand, the previous works already published help in unravelling the status of the problem taken up. The existing works help in identifying the research gaps as well after careful scrutiny, which in a way helps to keep the research continuum intact. Apart from learning insights from the published literature, the objectives can also be formed in line with the problem taken up. Another advantage of literature review lies in the assessment of analytical tools to be used, making the study more empirical.

12.1 Structural changes growth-instability trade-offs

Nayak *et al.* (2021) conducted a study using time series data for 48 years to analyze growth and instability of groundnut production in both Karnataka and India. The study was conducted in three time periods, and it was revealed that the middle period was found to have the highest level of instability in terms of land area followed by last and first period. It was also observed that the yield and production volatility was highest in the third period. The study suggested that the main reason for production volatility in both national and state level was due to changes in the total area under cultivation. This study emphasizes the importance of region-specific studies and policy measures for enhancing the production of the groundnut.

Adak and Pramanik (2024) analyzed the structural changes in input costs from the cost of cultivation data for West Bengal for paddy crop from 1999-2000 to 2019-2020. The study employed only nominal data and did not comprehend the same for constant prices. The

findings showed that the growth rate for rent paid for leased-in land was found to be higher for paddy in period I (1999-00 to 2009-10) at 34.44 per cent per annum. At the same time, the growth trends in terms of per cent per annum of major input costs for paddy were found to higher in period II (2010-11 to 2019-20) when compared to period I, such as human labour (10.27), machine labour (17.53), seed (9.49) and fertilizer cost (6.94). The growth rate of overall variable cost for paddy was higher in period II (9.42 per cent per annum) when compared to period I at 6.46 per cent per annum in nominal terms. Overall, the cost of cultivation analysis revealed the shift from labour-intensive agriculture to capital intensive agriculture in the state over the decades.

12.2 Break-even dynamics

Meena *et al*. (2013) in their study of estimating the breakeven analysis of garlic farmers in Baran district of Rajasthan across different farm sizes, found that the small, medium and large farmers could tolerate about 56, 54 and 54 quintals of yield loss before achieving break-even losses. A similar result was observed in break-even prices as the farmers we able to bear a loss of ₹987 to ₹1,015 per quintal before achieving actual loss. The study also revealed the constraints faced by garlic cultivators, such as high input costs and unstable market prices.

Rajput and Vani (2021) worked on plot-level data from the time period 2000-01 to 2016-17, for studying the decline in private agriculture investments in Madhya Pradesh. The study combined break-even analysis and trend analysis across major crops including, oilseeds, cereals and pulses. The results revealed that crops like cotton, black gram and soybean was less suitable for farmers facing resource constraints, while lentils had more stability. Cropping system combination of rice-wheat and cotton-gram were riskier and wheat was the only crop which showed a decline in trend of break-even output. The study also recommends an improvement in machinery access to the farmers and also increase in research projects for yield enhancement in crops such as sorghum, maize and rice.

Vani *et al*. (2026) studied the plot level cost of cultivation data for the year 2019-20 for understand the economic viability of major crops in Madhya Pradesh, using both break-even analysis and probabilistic risk assessment methods. The study revealed that certain crops such as cotton, pigeon pea, and maize were more prone to losses, while crops like soybean and black gram showed severe distress, as the returns were not even able to cover even the variable costs. The study thus was very useful in understanding the extent of risk faced by the farmers.

12.3 Elasticity and decomposition of break-even output

Ninawe *et al.* (2020) conducted research on trends and instability of soyabean cultivation in Amravati district of Maharashtra using a 30 year-time series data from 1988 to 2018. The findings revealed that initially the growth in area and production were positive, but were decreased in the later periods. It was also observed that the increase in the output of soybean was mainly influenced by an increase in the cultivated area and not by improved productivity. The main reason for the instability in the crop was due to climate uncertainties. The study emphasized the need for improved technology and practices for sustainable growth. Finally, the study also revealed that the farmers decision of area distribution was less influenced by market prices in short run but was more responsive in long run.

Sandeep *et al.* (2015) computed the decomposition and area response of chickpea in Western Vidarbha region of Maharashtra using Nerlovian lagged adjustment model. He used time series data for rainfall and farm harvest prices and concluded that chickpea cultivation showed a significant progress in the initial years which subsequently declined and then recovered in the later periods. Yavatmal district was observed to be highly instable in the terms of production. The decomposition analysis revealed that area under the crop had a major role in influencing the output level, i.e. increased production as primarily due to increased area and not improvements in productivity.

12.4 Supply response of acreage to price and non-price factors

Dixit *et al.* (1998). studied the production behaviour of groundnut in Karnataka using Nerlovian adjustment model, highlighting the combined effect of market incentives and environment factors. The study revealed that high market prices had a positive impact on production over time. It was also observed that the farmers tend to choose the crops which have low risk factors as observed due to their negative relation. Average rainfall during the pre-sowing period also showed a very positive relation to area allotment. The study also concluded that higher fertilizer prices had negative while infrastructural development and advanced technology had a positive effect on input use and sustainable production of groundnut in rainfed areas.

Kumar (2017) studied the effect of market and environment factors on India's foodgrain supply from 1980 to 2014. The findings revealed that even though market prices had a positive effect of area expansion, but the major decision was impacted by historical planting patterns and non-price variables. It was observed that the crops like rice and wheat,

due to their heavy dependency on water showed a positive response to irrigation facilities while coarse crops had no significant effect due to their rain-fed nature. High input used and better climatic conditions had positive effect on yield. The study also concluded that even though better market conditions play a positive effect on production in short run, we still have to focus more on better irrigation infrastructure and input resource availability for a sustainable long run production.

Yadav *et al.* (2024) studied the economics of rice cultivation in the districts of Chhattisgarh, Orissa and Telangana using the cost of cultivation data. It was observed that all the three states had a very different approach towards rice cultivation, with Telangana working more on farm mechanizations, Orissa more oriented towards human labour and Chhattisgarh having a balanced approach. It led to an increased labour cost in Orissa and high machines cost in Telangana. Using the Generalized Method of Moments Model, it was found that fertilizer costs, seed quality and irrigation facility had a positive effect on the decision of area allotment under the crop in long run, and thus work should be done for enhancing these factors for sustainable production.

12.5 Total factor productivity

Ankhila *et al.* (2022) evaluated the Total Factor Productivity for rice and wheat in 12 agricultural states using a 25 year- time series data from 1991 to 2016. The study revealed that average productivity of growth slowed down between 2002 and 2015, compared to previous decade. It was observed that the increase in TFP was a result of advanced technology and not good resource management. The study concluded that the focus should be on improving the farmer's farm efficiency more than improving technology.

Chaudhary (2012) worked on the efficiency of agricultural production across different Indian states using Total Factor Productivity method by decomposing the productivity into technological progress and efficiency change. The findings revealed that very limited states have progressed in either component. In several states a decrease in efficiency was observed indicating sub-optimal technology utilization. It finally concluded that, for enhancing productivity both technological advancements and improved resource use efficiency is required across different regions of India.

Mukherjee *et al*. (2017) studied the growth of Total Factor Productivity of maize cultivation in Telangana using parametric approach in time series data from the period 2000-01 to 2012-13. The data was taken from secondary sources like the cost of cultivation

surveys and other government sources. The findings revealed a major 51% increase in TFP during the study period with an annual growth of 3.5%. Rainfall and irrigation were observed as the major reason for the growth. Agricultural research, extension and education also had a positive impact on TFP.

Jain *et al*. (2017) examined the Total Factor Productivity to analyze whether the increasing agricultural outputs is due to increased inputs or advanced technology, over the period 1980–81 to 2011–12. TFP growth was estimated using Tornqvist Index, across four phases. The findings revealed a significant increase during recovery phase, with annual growth rate of 5.41%. It also evaluated TFP growth under different price scenarios and labour adjusted cost, which revealed that about 88% of the output growth is due to resource use efficiency and better technology.

12.6 Resource use efficiency and technical efficiency

Suresh (2015) employed a non-parametric Data Envelopment Analysis (DEA) approach for analyzing the efficiency of agricultural production across different districts in India. For having a better understanding of the sources of inefficiency, overall efficiency was further divided into pure technical efficiency (PTE) and scale efficiency (SE). A total of 409 districts of India were covered under this study, with each district considered as an independent decision-making unit, and also considered per ha crop output value as the output measure. Fertilizer use, rainfall, irrigation, labor availability and degraded land were considered as major inputs. The result indicated that average level of technical efficiency was low, suggesting scope for increasing output without increasing the inputs. The study further revealed that major inefficiencies were related to managerial difficulties rather than economies of scale. It was observed that hilly areas were performing better than rain-fed regions. Factors such as infrastructure, education, and capital assets were found to have positive effect in efficiency while land degradation had negative impact, highlighting the importance of resource management for sustainable agricultural productivity.

Narayanamoorthy *et al.* (2017) studied the cost of cultivation data of six major crops namely wheat, gram, paddy, cotton, groundnut and sugarcane, using time series data from period 1985-86 to 2013-14 with the objective to examine the efficiency of input use in crop production over a time period. The study revealed an instability in input use efficiency reflected due to fluctuations in the output. It was also observed that major inputs like fertilizers, irrigation and quality seeds were also not used optimally. It was discovered that

contrary to old beliefs that high productivity states have higher efficiency, some low productive states were noted to have higher efficiency. Finally, in regression analysis it was observed that all the six crops were not efficiently utilized in both high and low productive regions.

Amrutha *et al.* (2018) worked on the economics and efficiency of little millet cultivation in rainfed areas of Tumkur and Chitradurga districts of Karnataka. The result concluded that little millets were more economically viable than ragi cultivation. It also regarded little millets as the potential crop against climate variability, malnutrition and poverty because of their climate resiliency and high nutrients. Data Envelopment Analysis method used for efficiency analysis revealed low economic efficiency with average technical and allocative efficency, indicating scope for improvement in the use of resources.

Ahmad *et al.* (2018) studied the resource use efficiency, growth and instability of sugarcane cultivation in major producing states of India during the period 2000-01 to 2015-16 using secondary data. The findings revealed a positive growth in the area, production and productivity at national level. States such as Uttar Pradesh, Uttrakhand and Gujarat had stable area while states like Uttar Pradesh, Uttrakhand and Tamil Nadu were observed to have stable yields. Technical efficiency was found to be 66% using Data Envelopment Analysis method, which indicated scope for increasing output at present technology. It was further observed that the cost can still be reduced by optimal input allocations and efficient utilization of resources. Finally, an increase in sugar export was also observed.

Singh *et al.* (2017) studied the resource use efficiency of cotton, wheat and paddy by the farmers of Punjab, by analyzing plot-level survey data obtained by the cost of cultivation scheme. The findings revealed that large farmers operate their farm more efficiently as compared to small farmers. It was also observed that the farmers can simply lower their input costs by better resource allocation, without affecting their production. Size of the farm and farmer's education level of the household head had a positive impact on resource use efficiency, while factors like fragmented landholdings, older age and environmental stress factors had a significant negative effect. According to DEA model, there is still a scope for growth, especially for the crops like cotton, wheat and paddy where the yields can improve by 27%, 7% and 24% respectively, without adding more resources.

13. Methodology

This section presents the study area, the nature of the data, and the methodology adopted to achieve the objectives of the study.

13.1 Description of the study

The present study will be analytical in nature and will be based entirely on secondary data. The study will be conducted in Gujarat state, which is one of the leading groundnut-producing regions in India. The analysis will utilize plot-wise data for the period 2002–2022, collected from official government sources such as the Directorate of Economics and Statistics, Government of India, Ministry of Agriculture and Farmers Welfare, Cost of Cultivation Scheme (CCS), and other published reports, journals, and relevant databases. The study will focus on examining various economic aspects of groundnut cultivation, including input utilization patterns and growth–instability trade-offs in input costs, break-even dynamics, elasticity and decomposition analysis, supply response, total factor productivity, and efficiency measures.

13.2 Nature and sources of data

The dataset covers all major crops across the states and it is not only regular but also comprehensive. The importance of the data can be gauged by its comprehensiveness, providing plot-level information of farmers. Plot-level information of farmers is so rich that the cost and returns of all crops cultivated by the farmers in a given year are covered, providing sufficient data for location-specific analysis. The farmers are changed every block-period, which usually comprises three years. The veracity of the data can be understood by the cost accounting method, by which the farmers are visited every day by the trained personnel for data collection. As taluka-wise data are to be collected under this scheme, designated centres are identified with trained man-power. Despite the micro-data covering plot-wise information of farmers on all major crops being available, only a limited number of works are being done over time.

14. Statistical Analysis/Econometric Analysis

The present study will utilize the following statistical and analytical tools to achieve the stated objectives:

14.1 Descriptive statistics

Descriptive statistics are used to organize and summarize data, providing insights into patterns and relationships within a dataset. (Parampreet, 2018). I includes:

i. **Mean:** Mean is a measure of central tendency used to represent the average value of a dataset. It is calculated by dividing the sum of all observations by the total number of observations.

$$\bar{x} = \frac{1}{n}\sum_{i=0}^{n} x_i$$

Where, $\sum_{i=0}^{n} x_i$= Sum of all observations

n= Total number of observations

ii. **Standard Deviation:** Standard deviation is a measure of dispersion that indicates how much the observations in a dataset deviate from the mean. It shows the extent of variability or spread in the data.

$$\sigma=\sqrt{\frac{\sum(X-\overline{X})^2}{N}}$$

Where, σ = Standard deviation

X = Individual observation

$\overline{X}$ = Mean of the dataset

N = Total number of observations

$\sum$ = Summation

iii. **Skewness:** Skewness is a measure of the asymmetry of a distribution around its mean. It indicates whether the data are spread more towards the left or the right side of the distribution.

$$\text{Skewness}= \frac{3(Mean- Median)}{Standard\ Deviation}$$

iv. **Kurtosis:** Kurtosis is a measure of the shape of a distribution that indicates the degree of peakedness or flatness relative to a normal distribution.

$$\text{Kurtosis}= \frac{\sum(X-\bar{X})^4}{N\sigma^4}$$

Where, X = Individual observation

$\overline{X}$ = Mean of the dataset

N = Total number of observations

σ = Standard deviation

The above statistical measures are based on standard methods as described by Gupta and Kapoor (2014).

15.2.2 Instability Analysis

Instability analysis is used to examine the degree of variability or uncertainty present in a dataset over time. It is commonly assessed using statistical measures such as the coefficient of variation, standard deviation, and instability indices. In the present study, fluctuations in area, production, and productivity of groundnut will be analyzed using the method proposed by Ray (1983), as applied in the previous studies (Nayak, 2021).

$$\text{Instability Index} = \text{Standard deviation of } \ln (Y_{t+1} / Y_t)$$

Where, Y_t represents the value of area, production, or yield in the current period, and

Y_{t+1} denotes the corresponding value in the subsequent period.

Additionally, the Cuddy–Della Valle index (Cuddy and Della Valle, 1978) will be used to estimate instability in groundnut across Gujarat. This index is widely regarded as a more appropriate measure than the simple coefficient of variation, as it adjusts for the influence of long-term trends commonly observed in time series data.

$$I_X = \frac{SD}{\bar{Y}} \sqrt{1\text{-}R^2} \times 100$$

Where, I_X = Instability Index

SD= Standard Deviation

$\bar{Y}$= Average value of the time series data

R^2= Coefficient of multiple determination (from time series)

15.2.3 Break-even analysis

Break-even analysis will be used to determine the levels of yield and price at which total returns from groundnut production will be equal to the total cost of cultivation. It provides an estimate of the minimum output and price required to avoid losses (Billore *et al*., 2020). For the present study, the break-even output will be estimated using the specification as follows:

$$\text{Break-even output } Q^B = \frac{F}{P - V} \quad When P > V$$

Where, Q^B, F, P and V indicate plot-wise break-even output, fixed cost, groundnut main-product price and average variable cost, respectively. Once the break-even output is determined, the breakeven yield will be calculated plot-wise as a ratio of break-even output and corresponding acreage under groundnut cultivation in the plot. Further, breakeven yield will be determined by dividing the estimated plot-wise break-even output by the actual yield reported under groundnut cultivation by the farmers.

As Q^B is the function of fixed cost, output price, and average variable cost, the elasticities of break-even output with respect to the cost and price factors will be estimated

using the following equation:

$$\frac{dQ^B}{Q^B} = \frac{\partial f}{\partial F}\frac{dF}{Q^B} + \frac{\partial f}{\partial P}\frac{dP}{Q^B} + \frac{\partial f}{\partial V}\frac{dV}{Q^B}$$

Further, the decomposition of sources of break-even output over time will be determined using the formula given below.

$$\frac{Q_t^B - Q_{t-1}^B}{Q_t^B} = \frac{(F_t - F_{t-1})}{(F_t - F_{t-1})Q_t^B} + E_P^{Q_{t-1}^B}\frac{(P_t - P_{t-1})}{(P_{t-1})} + E_V^{Q_{t-1}^B}\frac{(V_t - V_{t-1})}{(V_{t-1})}$$

15.2.4 Supply response analysis

The supply response analysis will be carried out using the Nerlovian lagged adjustment model (Nerlove, 1958). This model is based on the premise that farmers adjust their acreage decisions gradually over time in response to changes in economic factors, particularly prices. The model assumes that farmers form expectations about future prices based on past prices and adjust the actual acreage towards the desired level with a certain lag due to institutional and technological constraints. The supply response function will be specified as:

$$A_t = \alpha + \beta P_t - 1 + \gamma Z_t + \delta A_{t-1} + u_t$$

Where,

A_t = Area under groundnut in year t

P_{t-1} = Lagged price of groundnut

Z_t = Vector of non-price factors (e.g., rainfall, irrigation, technology)

A_{t-1} = Lagged area under groundnut

u_t = Error term

The coefficient of lagged price (β) will indicate the short-run response of acreage to price changes, while the long-run response will be derived by adjusting for the lagged dependent variable and he coefficient of lagged area (δ) will represent the speed of adjustment, indicating how quickly farmers adjust actual acreage towards the desired level.

15.2.5 Total factor productivity analysis

Total Factor Productivity (TFP) will be used to measure the efficiency with which inputs are utilized in groundnut production. It represents the portion of output growth that cannot be explained by the increased use of conventional inputs such as land, labour, and

capital. Thus, TFP will capture improvements arising from technological progress, better management practices, and overall production efficiency. In the present study, TFP will be estimated using the Tornqvist–Theil Index, a superlative index number approach that accounts for changes in input and output shares over time. This method is widely used in productivity analysis due to its ability to provide a flexible and consistent measure of growth (Verma *et al.*, 2021).

15.2.5.1 Construction of Total Output Index (TOI)

The Total Output Index will be constructed by aggregating the output using revenue shares as weights. It will be expressed as:

$$ln\left(\frac{TOI_t}{TOI_{t-1}}\right) = \frac{1}{2}\sum_j (R_{jt} + R_{jt+1})\, ln\left(\frac{Q_{jt}}{Q_{jt-1}}\right)$$

Q_{jt} = quantity of the j^{th} output in year t

R_{jt} = share of the j^{th} output in total revenue

This index captures the change in output over time by accounting for the relative importance of each output.

15.2.5.2 Construction of Total Input Index (TII)

The Total Input Index will be constructed by aggregating all inputs used in production, weighted by their respective cost shares. It will be calculated as:

$$ln\left(\frac{TII_t}{TII_{t-1}}\right) = \frac{1}{2}\sum_i (S_{it} + S_{it+1})\, ln\left(\frac{X_{it}}{X_{it-1}}\right)$$

Where,

X_{it} = quantity of the i^{th} input in year t

S_{it} = share of the i^{th} input in total cost

This index reflects the change in the level of input use over time.

15.2.5.3 Estimation of TFP Index (TFPI)

The TFP index will be calculated as:

$$TFPI_t = \left(\frac{TOI_t}{TII_t}\right) \times 100$$

The index will indicate changes in productivity by comparing output growth with input growth over time. The analysis will be carried out for the period 2002–2022.

15.2.6 Efficiency analysis

The study will attempt to determine both plot-wise resource use and technical efficiency levels in groundnut cultivation at state-level for India and district-level for Gujarat.

15.2.6.1 Resource use efficiency of groundnut cultivation

To determine the resource-use efficiency of groundnut cultivation in Gujarat and India, the plot-wise data at district and state levels will be utilized to fit the following Cobb-Douglas type production function for estimating the respective input-output relationships:

$$\mathbf{Y = a}X_1^{b_1}X_2^{b_2}X_3^{b_3}X_4^{b_4}X_5^{b_5}X_6^{b_6}e^{u}$$

The working model to be employed in the study is:

$$\mathbf{In\ Y = Ina + b_1 InX_1 + b_2 InX_2 + b_3 InX_3 + b_4 InX_4 + b_5 InX_5 + b_6 InX_6 + u}$$

Where: $\mathbf{Y}$ = Gross income of groundnut farmers (Rs/ha); $\boldsymbol{X_1}$= Seed cost (Rs/ha); $\boldsymbol{X_2}$=Cost of manure (Rs/ha); $\boldsymbol{X_3}$ =Fertilizer cost (Rs/ha); $\boldsymbol{X_4}$= Irrigation cost (Rs/ha); $\boldsymbol{X_5}$= Plant protection cost (Rs/ha); $\boldsymbol{X_6}$=Human labour cost (Rs/ha); $\mathbf{a}$ = Constant; and $\mathbf{b_i}$= Coefficients to be estimated, $\mathbf{u_i}$ = Error term. Once the elasticities (b_1, b_2, b_3,…,b_5) are estimated, they will be further used to determine the marginal value product of the respective inputs using the following specification:

$$\mathbf{MVP_{Xi} = b_i \frac{\overline{Y}}{\overline{Xi}} (P_Y)}$$

Whereas, MVP_{Xi} = Marginal value product of i^{th} input; P_Y= Price of output per unit (Rs.); $\overline{Y}$= Geometric mean of output; $\overline{Xi}$= Geometric mean of i^{th} input; and b_i= Regression coefficient of the corresponding input costs. Going further, the marginal fixed cost will be assumed a unity and ratio of MVP and MFC will be used to estimate the type of utilization of resources over space and time.

15.2.6.2 Data envelopment analysis for technical efficiency

The concept of efficiency measurement was initially proposed by Michael J. Farrell (1957) and later extended through the Data Envelopment Analysis framework by Abraham Charnes, William W. Cooper and Edwardo Rhodes (1978). Data Envelopment Analysis is a non-parametric, linear programming–based method that constructs a piecewise linear production frontier using observed input–output data. This approach does not require any

pre-specified functional relationship between inputs and outputs, making it well-suited for agricultural studies. In this context, efficiency will refer to the ability of farmers to utilize available resources optimally. A production unit will be considered more efficient if it produces a given level of output with fewer inputs or achieves higher output with the same level of inputs. The DEA technique will be applied to estimate the relative efficiency of individual groundnut farms by comparing them with the best-performing farms operating on the efficiency frontier. Efficiency scores will range between 0 and 1, where a value of 1 will indicate full efficiency, while values less than 1 will reflect inefficiency in resource use. In the present study, DEA will be employed to evaluate the performance of groundnut-producing farms and to identify relatively efficient production units. The analysis will be based on unit-level data obtained from the Cost of Cultivation Scheme for groundnut for the period 2002–2022. The data will be sourced from the Directorate of Economics and Statistics, Government of India. The dataset will include information on key inputs such as human labour, machine labour (tractor hours), seed rate, fertilizer use, irrigation, and other relevant inputs, along with output measured in terms of groundnut yield. For the analytical framework, it will be assumed that there are K farms, each using N inputs to produce M outputs. The inputs will be denoted by x_{jk} (j = 1, 2, …, n) and outputs by y_{ik} (i = 1, 2, …, m) for the k^{th} farm (k = 1, 2, …, K). The technical efficiency (TE) of each farm will be expressed as the ratio of weighted outputs to weighted inputs:

$$TE_k = \frac{\sum_{i=1}^{m} u_i y_{ik}}{\sum_{j=1}^{n} v_j x_{jk}}$$

Where y_{ik} will denote the quantity of the i^{th} output produced by the k^{th} farm, x_{jk} will represent the quantity of the j^{th} input used, and u_i and v_j will be the weights assigned to outputs and inputs, respectively. The objective will be to maximize the efficiency score of each farm subject to the constraint that it does not exceed unity:

$$\frac{\sum_{i=1}^{m} u_i y_{ik}}{\sum_{j=1}^{n} v_j x_{jk}} \leq 1$$

Where the non-negativity condition $u_i, v_j \geq 0$, ensuring that efficiency scores remain between 0 and 1. The model will be solved using linear programming for each farm individually to obtain optimal weights. The DEA model will be estimated under both constant returns to scale (CRS) and variable returns to scale (VRS). The CRS model will provide estimates of overall technical efficiency, while the VRS model will be used to derive pure technical efficiency by accounting for scale effects (Ahmad, 2018).

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